Grain Storage

REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 2 Period--Oct. 1 to Dec. 31, 1941

R. T. Cotton

Corn Storage

Turning and Screening*

The turning and screening of corn in steel bins in Illinois was continued during the past quarter, but at a slower pace than during the preceding quarter. The grain in approximately 5,007 bins had been turned and recleaned by Dec. 6, 1941. Totals of bins turned by counties are given in Table 1. Owing to the mildness of the weather the practice of cleaning out bin doorways and spraying the doorways as well as around the outside lower tier of the bins after turning, was continued up to the end of December. Floors of the bins were also sprayed with oil.

Table 1:--Turning by counties in Illinois.

County	No. bins in county	No. bins turned to Sept. 15, 1941	Approximate No. bins turned to Dec. 31,1941
Bureau	302	218	297
Champaign	655	140	250
Ford	722	206	309
Henderson	205	---	20
Iroquois	817	204	345
Knox	288	---	23
LaSalle	685	---	60
Lee	362	13	155
Livingston	691	102	256
Logan	470	277	420
McDonough	342	305	342
McLean	1006	719	895
Macon	342	---	50
Piatt	251	130	226
Sangamon	414	211	327
Tazewell	163	25	40
Vermilion	495	307	403
Warren	556	139	245
Whiteside	595	242	344

* Results of turning and screening operations in Illinois from Report of J. M. Magner relating to cooperative work with Dr. M. D. Farrar of the Ill. Nat. Hist. Survey and Mr. E. V. Dabney of the Ill. A.A.A.

In December a study of 80 bins was made to discover, if possible, any relationship between date of turning and screening of corn in steel bins to that of reinfestation by insects carried back by the grain stream. Bins which had been turned in February, June and September 1941 were selected, the dates of turning being as near the first two weeks of each month as possible. The three counties selected and the types of machine used by each follow:

Ford	Rotary screen
McDonough	Converted sheller
McLean	Long Screen

It was planned originally to select 30 bins in each of three counties, 10 bins at each of the three seasons, but the rotary type screen in Ford County had not been in operation long enough to cover the three seasons of 1941 selected for the special study.

Ten probe samples were made at the surface near the center of each bin by means of a five foot grain probe. Each sample was screened in its respective bin, and the screenings brought to Urbana for examination for live insects.

In the following table of live insect counts it seems quite apparent that the long screen is far more efficient than either of the other types in screening out insects. A discrepancy seems to occur at Randolph in McLean County in the February screened bins where there are almost as many foreign grain beetles alone as there are all other insects in the 80 bins. Since the foreign grain beetle is a very strong flyer this very heavy infestation may, no doubt, be attributed to reinfestation by migration rather than a reflection on the efficiency of the long type screen.

One sample taken from a Macomb bin contained 500 dead sawtooth beetles which were not taken into consideration in the table. This was the only sample of the 80 which contained any dead insects. The bin had been fumigated between the time it was turned and the sample was taken.

Table 2:--Relationship of type of apparatus and time of turning to reinfestation in corn bins.

Turning apparatus	County	Rust-red flour beetle	Foreign grain beetle	Sawtooth beetle	Indian meal moth	Granary weevil	Rice weevil	Flat-grain beetle	Typhaea stercorea	Anthocorids	Hymenopterous parasites	Grain mites	Book lice	Miscellaneous larvae	Total	Date bins turned	Date sample taken
Converted sheller	McDonough		1	86				3		1	1				92	3/4 -2/11	12/17
Long screen	McLean	14	807	10		1	1	6	1	3			1	1	845	2/11-2/17	12/18
Rotary screen	Ford	1	42	58	4			25		6				1	137	6/2 -6/8	12/17
Converted sheller	McDonough	31	39	16	1	2	22	2		8					121	6/2 -6/11	12/20
Long screen	McLean	1	1	43	1			2	8			1			57	6/5 -6/7	12/18
Rotary screen	Ford	6	110	5				17	2		2			5	147	9/3 -9/13	12/17
Converted sheller	McDonough	13	5	82				54			1	2			157	9/4 -9/11	12/17
Long screen	McLean	1	15	59	2			3							80	9/1 -9/5	12/21

In connection with the turning and screening operation it is well to point out that in some sections of the Commercial Corn Area infestation in corn bins does not warrant wholesale turning. However, in order to turn and screen grain efficiently it is necessary to have an empty bin in which to transfer the grain from the first bin turned. It is then necessary to turn each bin on the site in consecutive order regardless of whether or not it is required. This involves a needless expense. Under such circumstances fumigation of infested bins would be more economical.

Cost of turning and cleaning varies from one-half to one cent a bushel. Although turning in cold weather is desirable, the presence of snow renders it a difficult or impossible operation in some regions. The disposal of infested screenings is a problem. They should be cared for locally instead of being shipped untreated by railroad.

Insect Infestation in Corn

In connection with the turning and cleaning of corn, observations were made on the presence and abundance of insects in the corn at the bottom of the bin.

Illinois*

During the past quarter the sawtoothed grain beetle, Oryzaephilus surinamensis L., was the most abundant species in steel bins of corn in Illinois. The hairy fungus beetle, Typhaea stercorea L., the flat grain beetle, Laemophloeus minutus Oliv., the foreign grain beetle, Ahasverus advena Watl., and the granary weevil, Sitophilus granarius, were next in abundance in order named. Evidence that the Indian meal moth is again starting to build up is shown by the fact that at some bin sites webbing is occurring on the grain surface. Live active larvae were observed during the first two weeks of December.

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* From observations of Magner, Farrar, and Dabney.

Iowa**

In Iowa examinations were made of samples of screenings taken from 810 bins of corn that were turned and cleaned during August and September.

Table 3 presents a summary of the relative abundance and distribution of insects, both dead and alive, by counties. It will be noted that 671 of the 810 bins examined contained live insects, at least in the samples of moist corn taken from the floors. This represents somewhat of an increase in the percentage of bins containing live insects as compared with the ratio in July.

Since a number of the bins classified as having live insects present contained only one or two live insects per sample, Table 4 is presented to summarize the data on the relative numbers of live insects found in the various bins examined. Here again we find evidence of an increase in the numbers of live insects per sample in the bins turned and cleaned during August and September. At the same time it is still apparent that over half of the bins examined were not threatened with any immediate danger of serious losses due to insect infestation.

Table 5 presents a summary of the relative abundance of the various species of stored grain insect pests encountered in the 810 bins examined during August and September. It will be noted that of the living insects the sawtooth beetle and the flat grain beetle were most frequently encountered and that such insects as the rust-red flour beetle, foreign grain beetle, granary weevil, hairy fungus beetle and Cynaeus angustus were present in from approximately 10 to 30 percent of the bins whereas other grain-infesting insects were only occasionally encountered. These observations are in agreement with the findings in July and with a survey made in March, 1941.

The examination of samples from bins being turned and cleaned was discontinued on October 1, but similar observations may be made in 1942 if turning and cleaning is continued.

** Report by Dr. Geo. C. Decker of the Entomology Department of the Iowa Agr. Exp. Station.

Table 3:--A summary of data on the relative abundance and distribution of insects, dead and live, by counties, in samples of corn taken from the floors of bins being turned and cleaned August and September, 1941.

County	Number of bins examined	Number of bins infested	Number of bins having live insects	Percent of infested bins containing live insects
1939 bins				
Butler	26	26	26	100
Calhoun	56	55	48	87
Cerro Gordo	26	26	22	88
Clarke	56	56	56	100
Dallas	23	23	23	100
Des Moines	6	6	6	100
Franklin	34	34	33	97
Fremont	30	30	30	100
Grundy	7	6	6	100
Guthrie	1	1	1	100
Hardin	52	45	41	93
Louisa	12	12	11	91
Lyon	92	74	56	76
Marion	36	36	36	100
O'Brien	16	16	16	100
Plymouth	27	24	7	29
Polk	35	35	35	100
Sioux	8	5	5	100
Union	34	34	33	97
Woodbury	17	17	13	77
Wright	40	40	40	100
Total	634	601	544	
1940 bins				
Butler	4	4	4	100
Cerro Gordo	41	33	31	93
Clarke	2	2	2	100
Des Moines	12	11	9	82
Grundy	1	1	1	100
Hardin	5	5	5	100
Louisa	9	8	7	88
Lyon	26	19	14	74
O'Brien	24	23	21	91
Plymouth	48	37	29	78
Union	4	4	4	100
Total	176	147	127	

Table 4:--A summary of data on the number of live insects per sample in floor samples of bins being turned and cleaned, August and September, 1941.

County	Number of bins containing live insects								Total bins with live insects
	Number of live insects per sample								
	1	2-3	4-5	6-10	11-25	26-50	51-100	100+	
1939 bins									
Butler	1	0	1	4	4	2	8	6	26
Calhoun	6	5	4	8	6	4	2	13	48
Cerro Gordo	1	0	1	5	5	6	0	4	22
Clarke	0	2	2	6	11	12	8	15	56
Dallas	0	0	0	1	3	10	6	3	23
Des Moines	0	1	0	0	2	1	0	2	6
Franklin	1	2	2	3	3	8	8	6	33
Fremont	1	2	0	3	3	2	4	15	30
Grundy	0	0	0	1	1	1	2	1	6
Guthrie	0	0	0	0	0	0	0	1	1
Hardin	1	3	3	2	7	10	4	11	41
Louisa	1	1	0	1	3	1	1	3	11
Lyon	12	14	11	8	6	3	1	1	56
Marion	0	2	0	1	3	4	6	20	36
O'Brien	2	0	0	1	5	2	3	3	16
Plymouth	2	4	0	0	0	1	0	0	7
Polk	0	0	1	0	5	3	3	23	35
Sioux	1	1	2	1	0	0	0	0	5
Union	3	2	0	3	12	3	3	7	35
Woodbury	2	3	1	1	3	1		2	13
Wright	1	0	1	2	5	7	11	13	40
Total	35	42	29	51	87	81	70	149	544
1940 bins									
Butler	0	0	0	1	0	1	0	2	4
Cerro Gordo	2	0	3	4	6	8	1	7	31
Clarke	0	0	0	0	0	1	0	1	2
Des Moines	0		0	1	3	2	0	3	9
Grundy	0	0	0	0	0	0	1	0	1
Hardin	0	0	0	0	1	3	1	0	5
Louisa	0	1	0	1	3	2	0	0	7
Lyon	2	2	1	6	2	1			14
O'Brien	0	2	1	4	3	7	2	2	21
Plymouth	7	6	6	4	3	1	2		29
Union	1	1	0	1	1	0	0	0	4
Total	12	12	11	22	22	26	7	15	127

Table 5:--A summary of data on the comparative abundance of stored grain pests in samples taken from floor of bins turned in August and September, 1941.

Species	Filled in 1939				Filled in 1940			
	No. of bins infested	No. of bins containing live insects	Percent dead*	Percent of bins containing live insects	No. of bins infested	No. of bins containing live insects	Percent dead*	Percent of bins containing live insects
Rust-red flour beetle	172	98	43	15	14	13	7	7
Foreign grain beetle	396	202	49	32	112	92	18	52
Sawtooth beetle	421	394	6	64	86	77	11	44
Granary Weevil	162	107	33	17	31	22	29	12
Rice weevil	24	12	50	2	5	5	0	3
Flat-grain beetle	362	310	12	49	48	37	23	21
Typhaea stercorea	331	164	50	26	91	61	33	35
Cynaeus angustus	190	106	48	17	17	10	41	5
Cadelle beetle	76	58	23	9	10	8	20	4
Black flour beetle	18	11	39	2	4	2	50	1
2-banded fungus beetle	94	36	62	6	12	7	42	4
Yellow-meal worm	31	5	82	1	3	1	66	T
Platydema ruficornis	11	1	91	T	1	0	100	0
Trogoderma versicolor	27	13	52	2	2	1	50	T
Black carpet beetle	11	5	55	1	0	0		0
Other dermestids	7	2	71	T	1	0	100	0
Spider beetles	20	5	75	1	3	2	33	1
Cryptophagus Sp.	113	39	66	6	16	10	48	5
Carpophilus sp.	44	18	59	3	5	2	60	1
Anthicus floralis	9	0	100	0	2	0	100	0
Litargus balteatus	44	16	63	2	13	10	23	5
Mycetophagus bipustullatus	104	31	70	5	21	13	48	7
Coninomus sp.	21	19	10	3	5	4	20	2
Rust-red grain beetle	3	0	100	0	0	0		0
Anthocorids	124	69	44	11	21	15	29	8
Hymenoptera	35	30	14	5	2	1	50	T
Grain Mites		78		13		17		10
Book lice		27		5		4		2
Staphylinidae	18		63		1	1	0	T
Scarabaeidae	3	0	100	0	0	0		0
Mexican grain beetle	6	0	100	0	0	0		0
Silphid	0	0		0	1	0	100	0
Nitidulids	2	0	100	0	6	3	50	2
Histerid	8	2	75	T	0	0		0

* Percent of infested bins in which all specimens were dead.
T = Trace (less than 1 percent)

South Dakota***

Not enough samples of screenings from corn bins were available for examination to draw any conclusions regarding the relative abundance of grain infesting species. Specimens of the sawtooth grain beetle, the flat grain beetle, the foreign grain beetle, the granary weevil and Cynaeus angustus were represented.

*** Reported by Dr. H. G. Severin

Effect of Temperature on Insect Abundance

After considerable delay due to difficulty in obtaining materials thermocouples have been installed in experimental bins throughout the Commercial Corn Area as follows:

Illinois--Champaign, Iroquois, LaSalle, McDonough, Sangamon, and Whiteside Counties.
Iowa--Montgomery, Cerro Gordo, Osceola, and Henry Counties.
Minnesota--Traverse and Nicolett Counties.
Nebraska--Antelope and Richardson Counties.
South Dakota--Roberts and Minnehaha Counties.

Temperature readings and general conditions of the grain will be observed at monthly intervals, whereas grade and insect populations will be taken quarterly. The taking of uniform observations over so large an area should provide some interesting data regarding the relationship between temperature and insect abundance.

Insect conditions in bins receiving no treatment.*

In an attempt to discover the ultimate effect of uncontrolled insect infestation in corn stored in steel bins under Iowa conditions, bin #23, located at Boone, Iowa has been under observation for a period of 2 years, and the results to date are of considerable interest. Temperature and grade data have been supplied by Dr. H. J. Barre's office. Unfortunately, records covering the period June to December 1940 were lost by fire when the Agricultural Engineering building burned. Prior to September, 1941, only a light insect infestation had been noted, and bin temperature had remained normal. At that time, however, a decided rise in temperature occurred, and by mid-October, a portion of the grain in the central part of the bin had attained a temperature of 107° F. Samples taken at that time revealed a dense insect population throughout the bin, the average for all samples being 153 insects per 1000 grams of corn. The population was composed largely of 2 species--Cynaeus angustus (Lec.) and Tribolium castaneum (Herbst.).

The surface 6 inches of grain in the center of the bin became excessively moist and crusted, accompanied by the development of molds. It was estimated that 25 bushels of grain had gone out of condition. Subsequent samplings at frequent intervals have showed no deterioration or moisture increase in the grain mass, below the top 6 inches, even though high temperatures have existed in most parts of the bin. With the advent of cooler weather in November, bin temperatures remained high. As late as December 16 portions of the grain in the center of the bin were recorded as having a temperature of 97° F.--a drop of only 10° in spite of the much lower outside temperatures prevailing during November and December. However, as the surface 6 inches of grain cooled, more moisture condensed therein, and the surface insect population withdrew to a depth of 6 to 8 inches in the center of the bin. It is planned to follow closely the progress of the infestation in this bin, together with its ultimate effect on the quality of the grain. To date there has been no deterioration except in the top 6 inches.

Concurrent observations have been made in bin #6 at Boone. According to the records, it became necessary to fumigate this bin in August, 1940. Since that time infestation has remained relatively low, and temperatures have followed normal levels. Some crusting in the center of the bin has been noted, but only a small amount of grain is involved.

At Humboldt, Iowa another badly infested bin was allowed to remain untreated, although, according to Dr. Harold Gunderson, Extension Entomologist, Iowa Extension Service, in the fall of 1940 this bin was "hot", had a dense insect population, and was badly crusted and deteriorating on top. In mid-December, 1941, in company with Drs. Gunderson and Decker this bin was inspected. Insect population was greatly reduced and bin temperatures were near normal. There were approximately 8 inches of spoiled corn on top of the bin totalling about 50 bushels.

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* From Report of H. H. Walkden, U. S. Bureau of Entomology and Plant Quarantine, Ames, Iowa.

Fumigation*

Tests with Dowfume Br 10

Extensive tests in Illinois with this mixture indicate that the standard dosage of 2 gallons per 1000 bushels of corn can be relied upon to give satisfactory results. At Garden Prairie, Illinois on October 21, 1941, ten steel bins fumigated by the Boone County crew at the regular rate were checked to determine whether results obtained by a standard crew of fumigators would compare with results obtained in experimental fumigations. In all bins a 100 percent kill was obtained.

On December 1, 1941, a series of 8 heavily infested bins were treated with this mixture as follows: 2 bins received the regular 2 gallon dosage per 1000 bushels, 2 received a dosage of 3 gallons per 1000 bushels applied all at once, 2 received an initial dosage of 2 gallons per 1000 bushels followed in 5 days by an additional dosage of 1 gallon per 1000 bushels and the last 2 bins received an initial dosage of 1 gallon per 1000 bushels followed in 5 days by an additional dosage of 2 gallons per 1000 bushels. In all bins a complete kill was obtained in the check boxes. Grain temperature readings taken in these bins before and after fumigation indicated that temperatures which were abnormally high due to infestation were reduced to normal by the treatment.

Attempts to use chloropicrin as a warning gas with this mixture resulted in the conclusion that it would require at least 1 pound of chloropicrin for every 4 gallons of the mixture. This would be prohibitive from a cost standpoint.

Tests with chloropicrin

In admixture with carbon tetrachloride, chloropicrin was successfully used for the treatment of shelled corn in steel bins. Eight bins were treated at Macomb, Illinois on October 22 at the rate of 2 pounds of chloropicrin in 1 gallon of carbon tetrachloride per 1000 bushels of corn, with the result that in all bins all insects were killed in the check boxes. The use of a carrier gas apparently ensures proper distribution of the chloropicrin.

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* Reported by Magner, Farrar and Dabney.

Survival of insects in bins after fumigation and accuracy of probe method of testing kill.

On November 17 and 18 the grain in four bins at Anchor, Illinois that had been fumigated on October 13 was turned and cleaned. This offered an excellent opportunity to check the accuracy of the probe method of determining the insect kill in fumigated bins and also of determining the relative amount of survival in such bins. Insect survival in these 4 bins was determined by counting the living and dead insects in samples of grain taken at 3 foot intervals at center, half way to the side wall and at the wall. A grain scoopful was taken each time. In the following tabulation the condition in each bin is represented by the number of insects in 10 scoops.

Bin No.	Fumigant used	No. insects per 10 scoops: Alive	Dead	Percent insects: Alive	Dead
1	Dowfume Br 10	102	560	15.4	84.6
2	Dowfume Br 10	77	6270	1.2	98.8
3	Dowfume Br 10	210	1167	15.2	84.8
4	Methyl bromide	331	38681	.9	99.1

At the time these bins were fumigated one month earlier, a complete kill of insects was obtained in check boxes buried in the grain in the bins fumigated with Dowfume Br 10 whereas in the bin fumigated with methyl bromide alone a poor kill at the top and sides of the bin was indicated by the check boxes. This would indicate that the method used to check the kill was not entirely accurate. This method which has been described in previous reports consists of placing insects in gelatin capsules in the compartments of 11-foot probes which in turn are thrust into the grain. In the bins under discussion 5 probes were used to each bin being arranged 1½ feet apart in a line from the center to the side wall and buried perpendicularly in the grain.

Oil Treatment of Corn

Bins of corn that had been treated with surface applications of various types of oils in July were sampled in October and the samples referred to the Federal Board of Review in Chicago. All samples passed inspection. On December 23 the bins were examined for the presence of free oil, and measurements were taken of the depth of penetration of the oil.

From the data of Table 6 it will be noted that 5 months after treatment, many more of the bins receiving a straight oil treatment showed a heavy residue of free oil on the surface than was the case where the oil was applied with carbon tetrachloride. Since the purpose of the oil treatment is to trap incoming insects it is desirable to have free oil on the surface of the grain as long as possible. The use of straight oil would appear to afford the greatest protection and at the same time would be more economical.

Table 6:--Comparison of straight oil and oil-fumigant grain surface treatments.

Bin No.	Date treated	No. qts. oil	No. gal. CCl_4	Brand and type oil	Surface condition at time samples were taken August 16, 1941	U. S. Marketing Service grade	Surface condition at time samples were taken October 16, 1941	U. S. Marketing Service Grade Oct. 17, 1941	Amount free oil Dec. 23, 1941	Penetration in inches measured Dec. 23, 1941
					Free oil on surface		Coating light			
104	7/16/41	2	0	Sacony Protex	No depth	OK	No free oil. No depth	OK	light	1/2"
							IMML light			
234	7/16/41	4	0	" "	Free oil spotted	Sample grade	Free oil heavy. No depth			
					Medium to heavy	Musty odor	Several beetles trapped	OK	turned	--
236	7/16/41	4	2	" "	Free oil light	Sample grade	Free oil medium to			
						Musty odor	heavy	OK	"	--
235	7/16/41	6	2	" "	Free oil heavy	Sample grade	Free oil heavy. Beetles			
						Musty odor	IMM, P & L trapped	OK	"	--
497	7/16/41	2	0	Std. Red Eng.	Free oil heavy	Sample grade	No free oil. Very light			1
					No depth	Lt. oil odor	penetration	OK	none	--
499	7/16/41	4	0	" " "	Free oil med.	Sample grade	No penetration			1
						Lt. oil odor	No free oil. Fair coverage	OK	"	--
109	7/11/41	6	0	Dia. Paraffin	Free oil med.	Sample grade	No trace free oil			
					Several IMM	Lt. oil odor	IMM flying normal	OK	"	3
500	7/16/41	4	2	Std. Red Eng.	Trace of free oil	OK	No free oil. No pent.			
						Sample grade	Fair cov. Some IMM	OK	"	1
110	7/11/41	6	2	Dia. Paraffin	Free oil light	Lt. oil odor	Free oil medium	OK	light	2
498	7/16/41	6	2	Std. Red Eng.	Free oil light	Sample grade	Free oil lt. to med.			
					to medium	Lt. oil odor	Few IMM larvae & adults	OK	"	2
342	7/16/41	2	0	Conoco Redind	Free oil lt. to med.	Sample grade	No free oil. No pent.			
						Light oil odor	Moderate coating	OK	none	1/2
340	7/16/41	4	0	" "	Free oil heavy	Sample grade	Free oil medium			
						Lt. oil odor	Very good coating	OK	light	3/4
351	7/16/41	3	2	" "	Free oil heavy	Sample grade	Free oil med. Good cov.			
						Lt. oil odor	Very light pent.	OK	med.	2
350	7/16/41	4	2	" "	Free oil lt. to med.	Sample grade	No free oil. Very slt.			
					Live IMML on sur.	Lt. oil odor	pent. Few live IMML	OK	none	1 1/2

Table 6 - continued

233	7/16/41	2	0	Texaco 522	Free oil medium	OK	Trace free oil. No pent. Coating poor	OK	turned	--		
462	7/16/41	2	0	" 1519	Free oil heavy in spots. Lrg. ins. trap'd	Sample grade Lt. oil odor	Free oil light no depth Good coverage	OK	light	1		
100	7/16/41	4	0	" 522	Free oil heavy	OK	Free oil heavy. Lt. pent. Surface very oily	OK	turned	--		
454	7/16/41	4	0	" 1519	Free oil very lt.	Sample grade Lt. oil odor	Free oil med. No pent. Oil coating good	OK	medium	1		
106	7/11/41	6	0	" 1519	Free oil very hvy. Ins. trap'd	Sample grade Lt. oil odor	Free oil med. Many insects trapped	OK	medium	3/4		
107	7/14/41	6	0	" 519	Free oil med. Surface very dirty	OK	Free oil light. IMML and adults trapped	OK	heavy	1		
108	7/11/41	6	0	" 1519	Free oil heavy	Sample grade Lt. oil odor	Free oil med. to heavy. Many insects trapped	OK	light	1½		
112	7/11/41	6	0	" 1519	Free oil heavy	Sample grade Lt. oil odor	Free oil heavy Some insects trapped	OK	heavy	2		
105	7/11/41	8	0	" 519	Free oil heavy	Sample grade Lt. oil odor	Free oil medium Some insects trapped	OK	medium	1		
102	7/16/41	4	2	" 522	Free oil light	Sample grade Lt. oil odor	Free oil med. Good coating. few live IMML	OK	gurned	--		
111	7/11/41	4	2	" 519	Free oil med.	OK	Free oil light Oil coating good	OK	medium	½		
463	7/16/41	4	2	" 1519	Trace free oil	Sample grade Lt. oil odor	Free oil lt. Oil coating good. Many insects trap'd	OK	none	3		
101	7/16/41	6	2	" 1519	Free oil medium	OK	Free oil medium Oil coating very good	OK	turned			
103	7/16/41	6	2	" 522	Free oil med. to heavy	OK	Free oil lt. Fair oil coating. Few live IMML	OK	light	1½		
348	7/16/41	0	0	Check	None	OK	None	OK	none	0		
455	7/16/41	0	0	Check	None	OK	None	OK	none	0		

IMM--Indian Meal Moth adults IMML--Indian Meal Moth larvae
Straight oil applied through a 3/64 inch nozzle at 125 lbs. pressure
Treatments with CCl_4 applied through a 1/8 inch flat nozzle at 35 lbs. pressure

Wheat Storage

Condition of Wheat at Jamestown N. Dakota and Hutchinson, Kansas*

Contrary to expectations, the November samples of the wheat stored at Jamestown, North Dakota revealed that a considerable portion of the grain was infested with insects. Out of a total of 139 bins sampled, 26 samples or 19 percent were found to be infested; of this number, the wheat in two bins graded weevily.

Six species of stored grain insects were involved, the flat grain beetle being the dominant species, with the granary weevil ranking second in abundance (see Table 7). In addition grain mites were found in 16 bins.

Table 7:--Summary of insect populations found in October-November quarterly sampling, Jamestown, N. Dakota, and Hutchinson, Kans.

Species	Jamestown	Hutchinson
Lesser grain borer	0	530
Flat grain beetle	31	112
Rust red flour beetle	1	20
Rice weevil	1	101
Granary weevil	8	0
Sawtoothed grain beetle	0	4
Foreign grain beetle	2	4
Cadelle	0	3
Dermestid larvae	0	1
Conominus species	1	0
Larvae (species undetermined)	0	12
Totals	44	787
Bins infested with grain mites	16	0
Bins infested with book lice	0	15

* From Report of H. H. Walkden and R. B. Schwitzgebel.

As the samples were being taken, the grain surface was examined for the presence of insects. In this manner, insects were observed in 37 bins, but the average samples from 13 such bins showed no infestation. This situation raises the question of the adequacy of the sampling technique. It is planned to go into the matter of sampling methods more fully in order to determine the size of sample necessary to yield reliable infestation estimates. Some preliminary work along this line is now in progress at the Hutchinson bin-site, a nd the results indicate that a 1000-gram sample cannot be relied upon to give dependable results as to insect infestation and that it will be necessary to examine a sample of at least 3000 grams (approximately 3 quarts) in order to obtain a reasonably reliable estimate of the insect population. Further work on sampling technique is planned for the near future, as it is considered imperative that a reasonably accurate estimate of populations be obtainable due to the narrow margin set up by grain grading standards in determining the "weevily" grade (2 weevils, or 5 bran bugs, or 1 weevil and 2 bran bugs per 1000-gram sample render the grain weevily).

The insect situation at Hutchinson presents a strikingly different picture from that existing at Jamestown, North Dakota. Insect populations in many of the bins at Hutchinson have increased with much greater rapidity than was expected even though many bins received an initial fumigation. Early in October the infestation in one of the "no treatment" or check bins had reached alarming levels, and it was necessary to fumigate and thus eliminate it as a check. This bin was later reassigned and a cotton batt sprayed with oil was applied in November.

The October quarterly sampling at Hutchinson revealed that out of 143 bins sampled, 62 or 43 percent contained living insects and of this number, 15 or 10 percent graded weevily. Thirteen species of stored grain insects were found, the lesser grain borer being the dominant species, with the flat grain beetle ranking second in abundance (Table 7). The rice weevil was also abundant. Populations ranged from 0 to 122 insects per 1000-grams of grain. Bins grading "weevily" were fumigated during the latter part of October and uniformly good results were obtained.

During the last 3 months, temperature readings at 2-week intervals have been taken by means of thermocouples installed in the bins, so that it has been possible to observe temperature trends. In this way, the development of hot spots in the grain have been detected. Spot fumigations in those bins showing a temperature rise in local areas have apparently reduced insect populations with the result that a reassuring temperature drop has taken place in all bins so treated.

Two bins in the floor study series, namely those equipped with a single layer of 1-inch boards under the steel bin bottoms have developed excessive insect populations, but have shown no alarming temperature rise as yet. These are being watched closely.

The great difference in climatic conditions between Hutchinson and Jamestown affords an excellent opportunity to compare the effect of winter temperatures on insect survival in grain stored in steel bins. It is expected that the low winter temperatures prevailing at Jamestown will greatly reduce, if not eliminate insect populations in the bins at that location.

Fumigation of bins.

As a result of the October sampling, it was found that the wheat in 15 bins graded "weevily". These were fumigated in November, using Dowfume Br 10 at the rate of 2 gallons per 1000 bushels. This group included bins assigned to the management and floor investigation series, and it was deemed advisable to reduce insect populations to a low level in order to allow time for differentiation in management features.

Altogether, 48,000 bushels of grain were fumigated at a cost of $5.20 per 1000 bushels. It is believed that uniformly good results were obtained, although it is suspected that subsequent reinfestation may have occurred in some bins from outside sources.

Use of Cotton batts to cover grain.

Observations on the effectiveness of cotton batt covers as barriers against surface infestation of wheat in steel bins were begun during the quarter. Two batts were installed in bins containing approximately 2600 bushels of wheat each. One of these batts was put in place on the surface of the grain and then sprayed with 6 quarts of diamond-paraffin oil, applied as a mist under 60 lbs. air pressure. It was expected that the oil would soon soak into the cotton, but subsequent examinations showed that it has remained suspended in very fine globules on the ends of the cotton fibers over a period of two months. Several species of stored grain insects were released on the oiled surface of the batt and all became immobile within 3 minutes, and none were able to progress more than 10 inches from the point of release. This method of treating cotton covers with oil gives promise of being an excellent barrier, provided the globules of oil remain intact during hot weather.

Oil spray applied to the grain surface.

A series of bins designated to receive an application of oil on the grain surface was treated in November. The oil was applied at the rate of 2 quarts of oil per 1000 bushels of grain. One week after application oil had penetrated to a depth of 2 to 3 kernels of wheat. One month later oil had penetrated approximately $\frac{1}{2}$ inch.

Insect Infestation in Loan Wheat in Kansas*

During the period from October 1 to December 31, one hundred and twenty two infested samples of loan wheat were obtained from 39 different counties in Kansas. Of the 12 different species of insects represented in the samples the most abundant were the flat grain beetle, (1,573 specimens in 91 samples), the rice weevil (384 specimens in 52 samples), the rust red flour beetle (122 specimens in 36 samples), the sawtoothed grain beetle (111 specimens in 24 samples), and the granary weevil (87 specimens in 10 samples). Complete data regarding the infestation present in the samples are given in Table 8.

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* Reported by R. T. Cotton.

Table 8:--Insect infestation in samples of farm stored grain in Kansas, Oct. 1 - Dec. 31, 1941.

County	Number infested samples	Flat grain beetle	Rice weevil	Rust red flour beetle	Saw-toothed grain beetle	Granary weevil	Cadelle	Lesser grain borer	Small-eyed flour beetle	Foreign grain beetle	Hairy fungus beetle	Con-fused flour beetle	Indian meal moth
Barber	2	10(1)		1(1)			1(1)						
Barton	5	45(3)	8(2)	5(4)		9(2)				1(1)			
Bourbon	2		14(2)										
Chautauqua	1	1(1)			2(1)			2(1)					
Clark	2	21(2)	12(1)	6(1)		4(1)							
Commanche	4	50(4)	4(1)	14(2)	2(2)	18(1)							
Cowley	2	13(2)	3(1)	1(1)						1(1)			
Decatur	1	10(1)		1(1)									
Doniphan	2	12(2)	3(2)										
Ellis	2	19(2)											
Ellsworth	4	90(3)	8(2)	5(3)	14(2)					1(1)			
Ford	1	17(1)											
Gove	1	9(1)			3(1)								
Graham	2	47(2)			7(1)								
Harper	2	1(1)					1(1)	20(2)					
Harvey	3	70(2)	24(3)		4(2)						1(1)		
Hodgeman	2	109(2)											
Jewell	1												3(1)
Kiowa	4	68(3)		1(1)	42(2)								
Lane	3	74(3)	1(1)			5(2)							
Lincoln	1	23(1)	1(1)										
McPherson	17	97(11)	145(12)	22(8)	32(4)		2(1)		2(2)				
Mitchell	1	2(1)	2(1)			8(1)							
Montgomery	2	3(1)	53(2)	2(1)									
Ottawa	1	21(1)		3(1)	1(1)					3(1)			
Pawnee	4	61(4)	1(1)	4(1)									

Table 8 - continued.

County	Number infested samples	Flat grain beetle	Rice weevil	Rust red flour beetle	Saw-toothed grain beetle	Granary weevil	Cadelle	Lesser grain borer	Small-eyed flour beetle	Foreign grain beetle	Hairy fungus beetle	Con-fused flour beetle	Indian meal moth
Pratt	3	24(3)			14(2)				1(1)		8(1)		
Reno	8	54(6)	27(3)	5(2)	1(1)								
Republic	2	8(2)	1(1)		10(1)					2(1)			
Rice	8	96(2)	11(1)						1(1)				
Rooks	1		1(1)			1(1)							
Rush	2	1(1)	11(1)	1(1)	14(1)								
Saline	1	11(1)	2(1)	1(1)	1(1)				4(1)				
Sedgwick	1	6(1)	2(1)	1(1)									
Seward	1		2(1)										
Stafford	15	439(14)	29(4)	8(3)	2(2)	29(1)	1(1)					1(1)	
Stevens	1					13(1)							
Sumner	6	56(6)	16(5)	41(3)			3(2)	10(3)					
Woodson	1		3(1)										
Totals 39	122	1573(91)	384(52)	122(36)	111(24)	87(10)	8(6)	32(6)	8(5)	8(5)	9(2)	1(1)	3(1)

* Numbers in brackets indicate number of samples infested.

Moisture Requirements of Stored Grain Insects*

Tests to determine the effect of grain moisture on the survival and reproduction of our common stored grain insects have shown that both the percentage of survival and the ability to reproduce is largely dependent upon the moisture content of the grain. Considerable variation between different species of stored grain insects in their ability to survive is noted, but in all cases, the percentage of survival over a given period of time is greater in grain with a high moisture content, as compared with grain having a low moisture content. This fact was rather definitely established in earlier tests. Since in our first tests the different moisture variant grains were not tested under like temperature conditions, another series of tests was repeated. In these tests three moisture variants, namely, 9, 10, and 11%, were tested with four different stored grain insects, simultaneously. Table No. 9 shows the percentage of survival for these tests over a period of 15 weeks. It will be noted that in all species except the rice weevil, the percentage of survival at each examination increased with the increase in moisture content of the grain. The discrepancy as noted in the tests containing rice weevil is not at present explainable. However, in the 11% moisture series the rice weevil shows a higher percentage survival at each examination than is true of the 9 and 10% moisture series.

As these tests progressed it soon became evident that temperature is almost as important as the moisture content of the grain. Since the equipment used for these tests did not permit the employment of constant temperature control, the factor of temperature is not as clearly established. That temperature is a factor and within rather limited range, is indicated by comparison of two series of tests with 11% moisture corn, run at different seasons of the year. The first series was started on March 27, 1941 and completed on August 7, 1941. During this time the average daily temperature as recorded by a hygrothermograph was 76.4° F. During this period the daily mean temperatures ranged between 68° and 93° F. The second series was started on September 18, 1941 and is still in operation at this date. The average daily mean for this period was 71.3° F. and the range of daily mean temperatures was between 65 and 83° F. Table No. 10 shows a comparison of the percentages of survival of two species of grain infesting insects, from tests conducted under the above mentioned temperature conditions. A higher percentage of survival was obtained with each species in the test run when the average daily mean temperature was 76.4° F., as compared with the test conducted when the average daily mean temperature was 71.3° F.

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* From Report of R. T. Cotton and J. C. Frankenfeld.

Table No. 9:--Showing the percentage of survival of various stored grain insects when reared in 9, 10 and 11 percent moisture corn.

Species of Insects	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks
9 percent corn								
Granary weevil		16	12	11	11	10	9	8
Rice weevil		72	70	65	52	44	31	20
Confused flour beetle		88	86	86	84	84	84	84
10 percent corn								
Granary weevil		33	29	26	22	19	15	13
Rice weevil		42	40	38	35	32	20	11
Confused flour beetle		87	84	82	82	82	81	81
Rust red flour beetle		85	82	81	77	76	72	67
11 percent corn								
Granary weevil		81	75	73	72	71	69	66
Rice weevil		83	79	74	70	60	41	24
Confused flour beetle		95	93	90	89	89	88	88
Rust red flour beetle		97	94	93	89	89	88	88

Table 10:--Comparison of the percentage of survival of the rice weevil and confused flour beetle in 11% Moisture corn at different temperatures.

Average daily mean temperature	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	11 Weeks	13 Weeks	15 Weeks
Rice weevil								
76.4 Range 68-93°F.	100	100	96	94	92	88	62	0
71.3 Range 65-83°F.		83	79	74	70	60	41	24
Confused flour beetle								
76.4 Range 68-93°F.	100	98	94	94	94	92	92	90
71.3 Range 65-83°F.		95	93	90	89	89	88	88

The temperature and grain moisture combination is more pronounced in its effect upon reproduction in stored grain insects. In grain with a moisture content of 7, 8, and 9%, no reproduction was obtained with any of the common stored grain insects in spite of the fact that when these tests were in progress the daily mean temperature ranged well over 75° F.

When, however, the moisture content of the grain was increased to 9.5% and the daily mean temperatures ranged between 75 and 95° F., reproduction took place, almost at once and continued throughout the period of time these tests were conducted. At the end of five weeks many adult progeny of the original sawtoothed grain beetle colony were found in both corn and wheat cultures, and at the end of seven weeks adults of the confused flour beetle and the rust red flour beetle were appearing in the wheat cultures. Neither the rice weevil nor the granary weevil were able to reproduce in 9.5% moisture corn or wheat.

In another series, namely the 10% moisture series, the necessity of having the correct moisture and temperature combinations is even more strikingly illustrated. This series was started January 9, 1941 when the daily mean temperatures fluctuated between 60 and 70° F. No reproduction of any of the grain insects used took place until after the test had been in progress for 16 weeks, at which time the daily mean temperatures fluctuated between 70 and 75° F. Up until May 1st the daily mean temperature had never risen above 70° F. except on one or two widely separated dates. After this date, however, the daily mean temperature never dropped below 70° F. and more frequently remained between 75 and 80° F. During this latter period all species that had survived were reproducing. The original adults of the flat grain beetle and the lesser grain borer had practically all died off before May 1st and no reproduction was obtained in cultures containing these two species. The same or similar results are being obtained in the repeated series of 10% moisture corn which are now in progress. Fifteen weeks have elapsed and so far no reproduction of any species has occurred. The daily mean temperatures are generally below 70° F. and have been more or less so since this series was started.

In the 11% moisture series the same situation presented itself. This series was started on March 27, 1941, when the daily mean temperatures ranged between 65 and 71° F. These temperatures prevailed until the first week in May. First signs of reproduction were observed on May 15th when several small larvae of the sawtoothed grain beetle were found. By June 12, newly formed adults were appearing in all cultures, and each species included in this series reproduced freely.

In the repeated 11% moisture series now in progress, with the daily mean temperatures below 70° F. no reproduction has taken place after 15 weeks.

These preliminary tests on the effect of temperature and grain moisture indicate rather definitely that there are apparently well defined limits in which our common stored grain insects will or can breed. Future tests are planned in which both the temperature and the moisture content of the grain will be held constant to more definitely establish these limits.